REMARKS

Reconsideration of the pending application is respectfully requested on the basis of the following particulars.

1. In the claims

As shown in the foregoing LIST OF CURRENT CLAIMS, the claims have been amended to more clearly point out the subject matter for which protection is sought.

A. Claim amendments

Claim 1 is amended to delete the phrase "without a radiation-curing lacquer component." It is respectfully submitted that no new matter is added, since the amendment merely deletes previously added language.

Claim 27 is similarly amended so as to be commensurate in scope with amended claim 1. Again, it is respectfully submitted that no new matter is added, since the amendment merely deletes previously added language.

The amendments to the claims are made in order to reduce issues for appeal. Therefore, entry of the amendments to the claims is respectfully requested.

Further, amended claims 1 and 27 are now identical to corresponding claims 1 and 19 in co-pending European application no. 04 707 518, in which the Examining Division has issued a Communication pursuant to Rule 71(3) EPC ("Before the Examining Division decides to grant the European patent, it shall inform the applicant of the text in which it intends to grant it, and shall invite him to pay the fee for grant and publishing and to file a translation of the claims in the two official languages of the European Patent Office other than the language of the proceedings within a period of four months. If the applicant pays the fees and files the translation within this period, he shall

be deemed to have approved the text intended for grant.") informing the applicant of the text of the claims that the European Patent Office (EPO) intends to grant for the European patent.

Claims 2-4, 10-15, 17-26, 28-33, and 35-47 are left unchanged.

Claims 5-9, 16, and 34 remain canceled.

Claims 27-33 and 35-47 remain withdrawn from further consideration.

Entry of the LIST OF CURRENT CLAIMS is respectfully requested in the next Office communication.

B. <u>Rejection of claim 1 under 35 U.S.C. § 112 first paragraph</u>

This rejection is rendered moot, in view of the amendment to claim 1, on the basis that the identified language has been deleted from the claim.

Accordingly, withdrawal of this rejection is respectfully requested.

2. <u>Rejection of claims 1, 3, 4, 11, 13-15, 17, 21, 24, and 26 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent no. 5,820,971 (*Kaule et al.*) in view of U.S. patent no. 6,710,120 (*Gertzmann et al.*)</u>

Reconsideration of this rejection is respectfully requested, in view of the amendment to claim 1, on the basis that the rejection fails to establish a *prima facie* case of obviousness with respect to amended claim 1, from which claims 3, 4, 11, 13-15, 17, 21, 24, and 26 depend.

All of the previously submitted comments and observations on the *Kaule* and *Gertzmann* patents are hereby incorporated by reference.

By way of review, amended claim 1 recites at least in part, a protective layer having at least two lacquer layers, a physically drying first lower lacquer layer based on a water-based dispersion of aliphatic polyester polyurethanes or styrene-acrylic polyurethanes; and a second upper lacquer layer formed as any one of the following layers a), b), or c):

a) a radiation-curing UV-crosslinked lacquer layer;

b) a physically drying water-based dispersion lacquer layer based on styrene-acrylic without a polyurethane component;

c) a hybrid lacquer layer containing both physically drying components and a radiation-curing lacquer component, and based on aqueous dispersions on the basis of aliphatic urethane acrylates and acrylates with photoinitiators.

It is noted that each of the possible compositions used for the second lacquer layer is different from the recited possible compositions used for the first lacquer layer.

The Office action rejects claim 1 as being obvious in view of the proposed combination of the *Kaule* and *Gertzmann* patents.

As acknowledged on pages 3, 8 of the Office action, the *Kaule* patent discloses the use of UV-curable (radiation curable) and chemically curing coating compositions.

In particular, and as discussed in detail in previously submitted responses, the terms "reaction lacquer" and "reaction adhesive" are *defined* in the *Kaule* patent as lacquers or adhesives that cure, i.e. polymerize or cross-link, irreversibly under specific physical (i.e. radiation) or chemical activation (col. 3, lines 53-58).

Further, as acknowledged on pages 2 and 3 of the Office action, the *Kaule* patent specifically discloses that the lower reaction layer 4 and the upper reaction layer 2 are

largely homogenous chemically, in order to provide a very firm compound in areas where the metal layer contains pores or microcracks.

While the Office action notes on page 3 that such a requirement does not require the layers to be cured in the same way, it is respectfully reiterated that as previously pointed out, the *Kaule* patent only discloses the use of *curing* compositions, in which lacquers or adhesives that cure, i.e. polymerize or cross-link, irreversibly under specific physical (i.e. radiation) or chemical activation (col. 3, lines 53-58).

There is simply no suggestion in the *Kaule* patent to use a physically drying liquid lacquer layer for the lower layer in the *Kaule* patent, as is required by amended claim 1.

Further, the Office action indicates on page 3 that a person having "ordinary skill in the art would have found it obvious to use a chemically curing adhesive layer and a chemically curing or UV-curing embossed layer that is largely homogenous with the adhesive layer as an embodiment within the Specification of Kaule et al [*sic*] and have a reasonable expectation of success." Even if this assertion is true, the *Kaule* patent still fails to disclose the use of a physically drying liquid lacquer layer for the lower layer in the *Kaule* patent, as is required by amended claim 1.

Additionally, since a physically drying liquid lacquer layer will not cure (i.e. will not polymerize or cross-link), such a physically drying liquid lacquer layer will not be "largely homogenous chemically" to a lacquer or adhesive that cures, i.e. polymerizes or cross-links, irreversibly under specific physical (i.e. radiation) or chemical activation, as is required of the two layers of the *Kaule* patent.

The Office action turns to the *Gertzmann* patent in an attempt to cure the deficiencies of the *Kaule* patent. However, the Office action acknowledges on pages 8 and 9 that the *Gertzmann* patent discloses compositions containing "crosslinkers."

While the *Gertzmann* patent may disclose "hybrid" aqueous dispersions, similarly to the *Kaule* patent, all of the compositions of the *Gertzmann* patent are curable, i.e. polymerizes or cross-links, irreversibly under specific physical (i.e. radiation) or chemical activation.

The Office action on page 9 asserts that "The applied coating compositions" of the *Gertzmann* patent "form films that are dried (reads on physically drying) and may be (but are not required to be) further irradiated with UV light" where photoinitiators are included.

Firstly, while not all of the compositions disclosed in the *Gertzmann* patent include photoinitiators, it is respectfully submitted that all of the compositions disclosed in the *Gertzmann* patent include some form of curing, i.e. polymerization or cross-linking, irreversibly under specific physical (i.e. radiation) or chemical activation.

Secondly, it appears that the Office action is taking the position that a hybrid composition that includes some physical drying, which is followed by some form of curing, i.e. polymerization or cross-linking, irreversibly under specific physical (i.e. radiation) or chemical activation, reads on a "physically drying liquid lacquer layer" as recited in claim 1.

This interpretation is inconsistent with the specification as originally filed, and is also inconsistent with the understanding of a person having ordinary skill in the art.

The proper standard for interpreting claim language at the U.S. Patent and Trademark Office (USPTO) is that claims must be given their broadest reasonable interpretation *consistent with the specification* and *consistent with the interpretation that those skilled in the art would reach* (emphasis added; see MPEP § 2111, which references the Federal Circuit's decisions in *Phillips v. AWH Corp.*, 415 F.3d 1303, in *In*

re Am. Acad. Of Sci. Tech. Ctr., 367 F.3d 1359, and in *In re Cortright*, 165 F.3d 1353, 1359, 49 USPQ2d 1464, 1468 (Fed. Cir. 1999)).

As has been previously discussed on numerous occasions, the specification as originally filed makes a distinction between 1) a physically drying liquid lacquer layer, 2) a radiation curing/UV lacquer, and 3) a hybrid lacquer having both physically drying components and chemically curing components (at least in paragraphs [0007], [0011], [0013], [0014], [0015], [0019], [0039], [0040], and [0048] of the accompanying description in the specification as originally filed).

In particular, in paragraph [0007], it is discussed that conventional water-based lacquers are suitable as protective layers "only if a second component in the form of a crosslinking agent is added." Paragraph [0011] of the specification goes on to discuss that radiation-curing lacquers "have the disadvantage that residual monomers and free photoinitiators as a rule remain as very reactive components in the depressions and pores of the substrate after radiation curing" in dependence upon a number of factors.

In paragraph [0013] it is further discussed how such reactive components of a radiation curing lacquer layer would be deposited in the depressions and pores of the substrate, without the use of the inventive lower lacquer layer.

The physically drying lacquer layer used for the lower layer is discussed in detail in paragraph [0014], and no reference is made in this paragraph to radiation or chemically curing components to be used in the lower layer.

Further, in paragraphs [0015] and [0019], the use of an upper lacquer layer is discussed. In particular, the upper lacquer layer may be a *physically drying lacquer layer* (whereupon during drying, the water component is physically removed), *radiation-curing lacquers* (curing by irradiation, and having the above-noted disadvantages when used as a

lower lacquer layer), and *hybrid lacquers* (containing both physically drying components and radiation-curing components).

As discussed in detail in the specification as originally filed, the radiation-curing lacquers and hybrid lacquers are only used as the upper lacquer layer, which is applied over the lower lacquer layer, in order to avoid the above-noted disadvantages with regard to radiation-curing lacquers leaving reactive components in the depressions and pores of the substrate after radiation curing.

Specifically, according to paragraph [0010] of the disclosure, the physically drying lower lacquer layer is applied to the substrate to close the pores of the substrate, so that the radiation-curing lacquer components of the upper layer do not leave reactive components in the depressions and pores of the substrate after radiation curing.

Using any type of curing lacquer layer or hybrid lacquer layer as the lower lacquer layer recited in claim 1 would defeat the purpose of the disclosed embodiments of using the *physically drying lacquer layer* as the lower layer in order to prevent migration of uncured reactive components into the pores of the substrate. Thus, the position in the Office action that a *hybrid* layer that has physically drying components and curing or cross-linking components, can be considered to be a *physically drying lacquer layer* is completely adverse to the structure and function of the *physically drying lacquer layer* recited in claim 1, and is therefore an untenable position.

Further, as evidenced by the attached excerpt from "Handbook of Print Media" (copy attached as appendix A), the common understanding of a person having ordinary skill in the art at the time the invention was made is that there is a distinction between drying effected by 1) chemical reaction, 2) physical processes, and 3) a combination of both (i.e. hybrid) (page 166, col. 1, second paragraph).

The chart on page 167 of the "Handbook of Print Media" clearly delineates the distinction between "physical" drying and "chemical" drying.

Thus, a person having ordinary skill in the art would have understood the recitation in claim 1 of a *physically drying lacquer layer* to be a lacquer layer that only dries by physical mechanisms, and not a *hybrid* layer, which may dry by physical mechanisms and by chemical (curing; polymerization) mechanisms.

Therefore, even if a person having ordinary skill in the art were to look to the *Gertzmann* patent to substitute coating compositions for the layers of the *Kaule* patent, since the *Gertzmann* patent only discloses chemically curing or hybrid compositions, the proposed combination of the *Kaule* and *Gertzmann* patents still fails to disclose a lower lacquer layer that is a *physically drying lacquer layer*, as is required by claim 1.

Accordingly, for at least these reasons, it is respectfully submitted that the proposed combination of the *Kaule* and *Gertzmann* patents fails to establish a *prima facie* case of obviousness with respect to amended claim 1, from which claims 3, 4, 11, 13-15, 17, 21, 24, and 26 depend, and withdrawal of this rejection is respectfully requested.

3. Rejection of claim 2 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent no. 5,820,971 (*Kaule et al.*) in view of U.S. patent no. 6,710,120 (*Gertzmann et al.*) and further in view of U.S. patent no. 5,928,471 (*Howland et al.*)

Reconsideration of this rejection is respectfully requested, on the basis that the rejection fails to establish a *prima facie* case of obviousness with respect to amended claim 1, from which claim 2 depends.

With respect to the proposed combination of the *Kaule*, *Gertzmann*, and *Howland* patents, it is respectfully submitted that the *Howland* patent fails to provide for the

shortcomings of the proposed combination of the *Kaule* and *Gertzmann* patents, as discussed above in detail with respect to amended claim 1, from which claim 2 depends.

Accordingly, withdrawal of this rejection is respectfully requested.

4. Rejection of claims 12, 19, and 20 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent no. 5,820,971 (*Kaule et al.*) in view of U.S. patent no. 6,710,120 (*Gertzmann et al.*) and further in view of U.S. patent no. 6,715,750 (*Gerlier et al.*)

Reconsideration of this rejection is respectfully requested, on the basis that the rejection fails to establish a *prima facie* case of obviousness with respect to amended claim 1, from which claims 12, 19, and 20 depend.

With respect to the proposed combination of the *Kaule*, *Gertzmann*, and *Gerlier* patents, it is respectfully submitted that the *Gerlier* patent fails to provide for the shortcomings of the proposed combination of the *Kaule* and *Gertzmann* patents, as discussed above in detail with respect to amended claim 1, from which claims 12, 19, and 20 depend.

Accordingly, withdrawal of this rejection is respectfully requested.

5. Rejection of claim 18 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent no. 5,820,971 (*Kaule et al.*) in view of U.S. patent no. 6,710,120 (*Gertzmann et al.*) and further in view of U.S. patent no. 6,905,711 (*Tullo et al.*)

Reconsideration of this rejection is respectfully requested, on the basis that the rejection fails to establish a *prima facie* case of obviousness with respect to amended claim 1, from which claim 18 depends.

With respect to the proposed combination of the *Kaule*, *Gertzmann*, and *Tullo* patents, it is respectfully submitted that the *Tullo* patent fails to provide for the

shortcomings of the proposed combination of the *Kaule* and *Gertzmann* patents, as discussed above in detail with respect to amended claim 1, from which claim 18 depends.

Accordingly, withdrawal of this rejection is respectfully requested.

6. Rejection of claim 25 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent no. 5,820,971 (*Kaule et al.*) in view of U.S. patent no. 6,710,120 (*Gertzmann et al.*) and further in view of U.S. patent no. 4,462,866 (*Tooth et al.*)

Reconsideration of this rejection is respectfully requested, on the basis that the rejection fails to establish a *prima facie* case of obviousness with respect to amended claim 1, from which claim 25 depends.

With respect to the proposed combination of the *Kaule*, *Gertzmann*, and *Tooth* patents, it is respectfully submitted that the *Tooth* patent fails to provide for the shortcomings of the proposed combination of the *Kaule* and *Gertzmann* patents, as discussed above in detail with respect to amended claim 1, from which claim 25 depends.

Accordingly, withdrawal of this rejection is respectfully requested.

7. Rejection of claims 22 and 23 under 35 U.S.C. § 103(a) as being unpatentable over U.S. patent no. 5,820,971 (*Kaule et al.*) in view of U.S. patent no. 6,710,120 (*Gertzmann et al.*) and further in view of U.S. patent no. 6,059,914 (*Suss*) and even further in view of U.S. patent no. 4,462,866 (*Tooth et al.*)

Reconsideration of this rejection is respectfully requested, on the basis that the rejection fails to establish a *prima facie* case of obviousness with respect to amended claim 1, from which claims 22 and 23 depend.

With respect to the proposed combination of the *Kaule*, *Gertzmann*, *Suss*, and *Tooth* patents, it is respectfully submitted that the *Suss* and *Tooth* patents fail to provide

for the shortcomings of the proposed combination of the *Kaule* and *Gertzmann* patents, as discussed above in detail with respect to amended claim 1, from which claims 22 and 23 depend.

Accordingly, withdrawal of this rejection is respectfully requested.

8. Allowable subject matter

The applicants gratefully acknowledge the indication of allowable subject matter in claim 10. However, in view of the above discussion, it is respectfully submitted that independent claim 1 is patentable, and the features of claim 10 have not been rewritten in independent form at this time.

9. Rejoinder of withdrawn claims

In view of the amendment to withdrawn process claim 27, from which the remaining withdrawn process claims depend, to correspond to the product of independent claim 1, rejoinder of the withdrawn process claims is respectfully requested upon the allowance of independent claim 1, in accordance with MPEP § 821.04.

10. Conclusion

As a result of the amendment to the claims, and further in view of the foregoing remarks, it is respectfully submitted that the application is in condition for allowance. Accordingly, it is respectfully requested that every pending claim in the present application be allowed and the application be passed to issue.

Please charge any additional fees required or credit any overpayments in connection with this paper to Deposit Account No. 02-0200.

If any issues remain that may be resolved by a telephone or facsimile communication with the applicants' attorney, the examiner is invited to contact the undersigned at the numbers shown below.

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HEIDELBERG

Helmut Kipphan (Ed.)

Handbook of Print Media

Technologies and Production Methods

Including 1275 figures, mostly in color
and 92 tables

Springer

Appendix A

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1.7 Drying Methods

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The term "drying" includes all processes taking place after the ink transfer, for instance, from the blanket or printing plate onto the substrate, thereby providing a stable linkage between the substrate and the printing ink. The printing ink solidifies during the course of this process, creating a prerequisite for reliable print finishing and later use of the printed products.

Depending on the ink build-up, drying is effected either by chemical reaction (oxidation or polimerization) or by physical processes (penetration, evaporation) or by a combination of both. Figure 1.7-1 shows an overview of the drying methods and their primary fields of application.

Figure 1.7-2 shows a sheet-fed offset press with several drying systems integrated into the delivery. Different drying methods for inks and varnishes often require different systems – also in the form of combined systems – for an optimum drying process. It can be useful to install both an IR and a UV dryer to ensure a variable capability of the printing press (see also figs. 2.1-58 and 2.1-60).

The structure of the printing inks has to meet two opposing requirements with regard to the drying properties:

- no drying on the rollers during press operation or short standstill periods,
- fast drying and anchoring on the substrate after printing.

The following factors are the most crucial ones for the drying properties of the printing inks:

- the ink's composition, above all with regard to the vehicle used, the carrier and relevant additives,
- characteristic features of the material to be printed (penetration capacity, etc.),
- printing conditions (ink quantity transferred, pile height, printing speed),
- climatic conditions (humidity, room temperature),
- dryer construction (air stream on the ink surface, reaction period, type of energy supply, etc.).

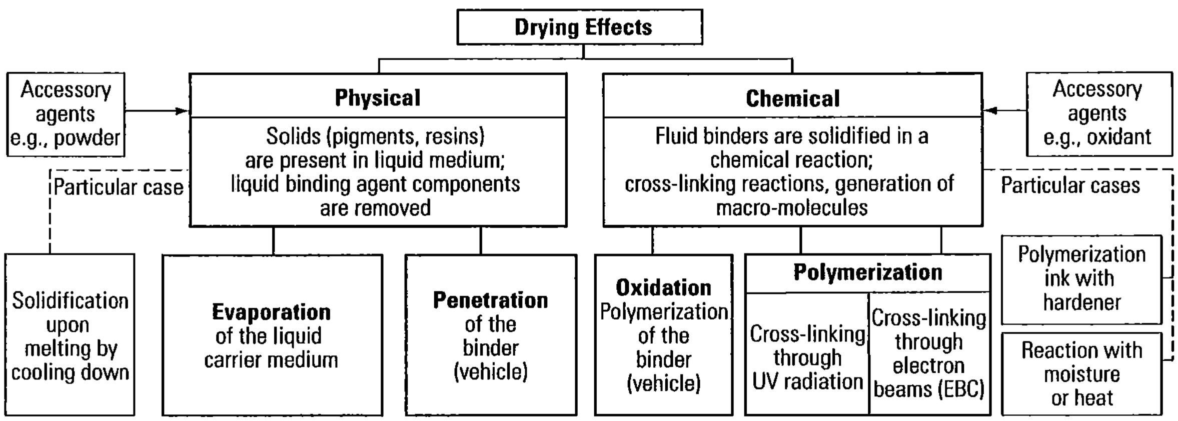
The temperature is a decisive factor – in general, higher temperatures are beneficial:

- the polymerization speed is accelerated,
- the ink viscosity is reduced to support penetration,
- there is faster evaporation of the solvents.

The degree of bonding between the inks and the substrate varies after the drying process is finished. As for the possible stress of the prints, there is a classification by the following characteristics: abrasion resistance, scratch proofing, scratch resistance, pile resistance, and wiping stability against wiping (see also sec. 1.7.4).

1.7.1 Physical Drying (Absorption)

Penetration is achieved by the interaction of printing ink and substrate (see also sec. 1.5.2). It depends above all on the carrier viscosity of the printing ink, the vehicle (binder) and the absorption capacity of the substrate.



a

Drying methods	Drying Effects: Evaporation	Penetration	Oxidation	Polymerization	Solidification	Two-component polymerization	Use (mainly)
Hot-air drying	**X**	x	(x)			x (Polymerization is accelerated)	Web offset (heatset) Gravure printing Flexo printing Screen printing Ink jet Dispersion varnish (water-based)
IR drying		**X**	(x)			x (Polymerization is accelerated)	Sheet offset
UV drying		(x)		**X**			Flexo printing Sheet offset Screen printing Varnishes
Excimer				**X**			Flexo printing
EBC				**X**			Web offset
Cooling (Hot-melt inks)					**X**		Ink jet

b

Symbols: **X** main effect; x, (x) further effects of less importance

Fig. 1.7-1 Drying processes.
a Overview of drying types and effects;
b Overview of drying methods, drying effects and fields of application

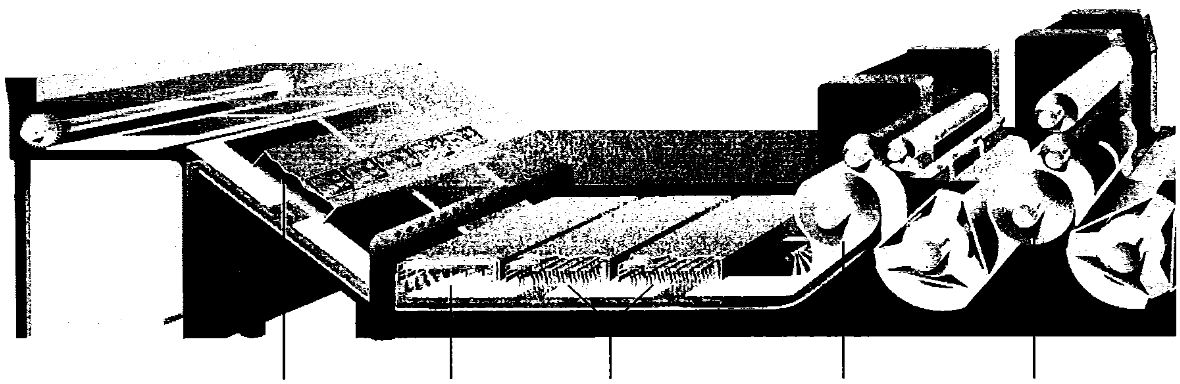


Fig. 1.7-2 Installation of different types of drying systems in a sheet offset press (Speedmaster CD, Heidelberg)

The printing ink components start *penetrating* with the transfer of the printing ink onto the paper and are sucked up into the paper by paper capillary tubes.

Consequently, penetration in the substrate depends on the *absorbency* and the *absorbing speed* of the substrate. The absorbing speed is determined by the porosity and the wetting quality. Porosity is characterized by the number of pores per area and the average pore diameter. Moreover, the absorbing speed is greater, the lower the viscosity of the printing ink.

Figure 1.7-3 explains the dependency of the ink penetration behavior on the absorption capacity of the substrate. In a test, the optical density of the ink film transferred on the counter sheet is measured relative to the drying period. (A counter sheet is an unprinted sheet unrolled defined on the freshly printed image. The optical density of the image reproduced on the counter sheet is measured, providing a value for the degree of drying.) Figure 1.7-3 shows that the non-absorbing substrate 1 still displays a very high counter print density after 120 minutes – it has not yet fully dried. Penetration is improved by smaller substrate pore sizes.

Too high an absorption capacity of the substrate can cause the printing ink to deplete vehicles. The ink loses brilliance and abrasion resistance and pigments can be wiped off. That is why papers with a good separation effect, that is, papers with a high *density of small pores*, are usually the optimum substrate for fine print results and for drying (e.g., art paper).

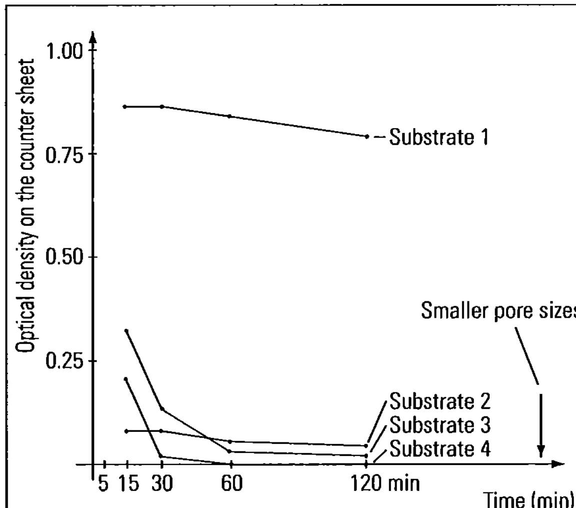


Fig. 1.7-3
Penetration behavior of ink (counter-print density) relative to substrate and time

Penetration depends on the absorption capacity of the substrate, but also on the viscosity (fig. 1.7-4) of the printing ink [1.7-1]. Absorbing speed also depends on the wetting behavior between the printing ink and the substrate.

In newspaper printing, *drying is effected by mere penetration* (coldset). The penetration process is carried out in a split second and the drying process is finished. Usually, printing inks used in newspaper printing do not contain drying oils (mineral oils). In cases where printing inks are used whose vehicles consist of drying oils, chemical drying by oxidation is triggered after penetration (see sec. 1.7.2).

1.7.1.1 Infrared (IR) Drying

Penetration of a printing ink is faster if the viscosity is low. Viscosity decreases when the temperature is raised. The transferred ink film can be heated up together with the substrate by using an IR radiation source (fig. 1.7-2). The IR drying effect in offset printing can be described in the following way:

- Lowering of the ink oils' *viscosity* by heating results in faster penetration.
- *Oxidation* in the warm pile is faster.

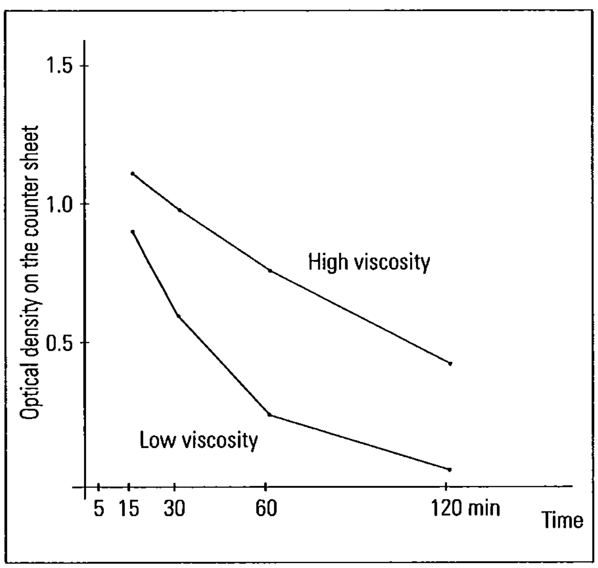


Fig. 1.7-4
Penetration behavior of ink (counter-print density; see also fig. 1.7-16) relative to ink viscosity and time

- Oxidation is accelerated by smaller *proportions of water* in the ink layer applied.

The chemical drying process (oxidation) following the physical drying process is also accelerated by a rise in temperature (see sec. 1.7.2).

The above processes are detectable in almost any kind of offset ink. Harmonizing IR radiation ranges and vehicle components absorbing within these frequency ranges helps to improve the effect of the radiators. Optimum effect of an IR radiator is achieved if maximum energy of the radiator and maximum penetration of the printing ink (or the varnish) coincide.

Wave ranges of the IR spectrum within the electromagnetic radiation spectrum are shown in figure 1.7-5. Infrared radiators are used in the following ranges of wave length:

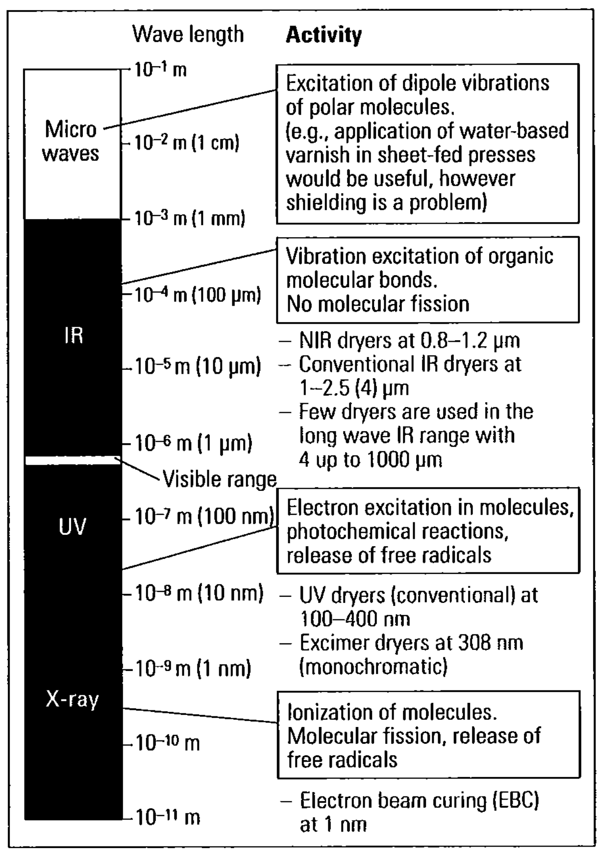


Fig. 1.7-5 Electromagnetic radiation spectrum for ink drying

- *short-wave* (0.8–2 μm, corresponding to a spiral-wound filament temperature of 2700–1500 °C), radiation penetrates mainly into the paper;
- *medium-wave* (2–4 μm, corresponding to 1500–750 °C), the air is heated mainly above the ink layer.

Experience has shown that optimum *absorption of ink* is achieved with short- or medium-wave IR radiators. Moreover, the short-wave radiator has a higher G-value (radiation efficiency). The so-called NIR dryers (near infrared, 0.8–1.2 μm) work in the lower short-wave range. Due to low efficiency, long-wave radiators (4 μm to 1 mm) are not suitable for offset drying.

As penetration is particularly important for fast drying, IR drying is most effective only if absorbent substrates are printed on. Figure 1.7-6 gives a description of the *IR radiation effect* on the penetration behavior.

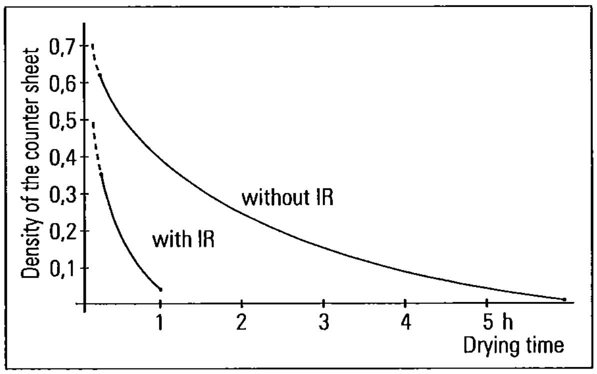


Fig. 1.7-6
Influence of IR radiation on penetration behavior (sheet-fed offset ink on coated paper)

The IR radiator heats unprinted areas in the paper, too, which results in an increase in the *pile temperature* (up to 40 °C) and an advantageous faster polymerization (see sec. 1.7.1). The pros and cons of IR drying are summarized in table 1.7-1.

1.7.1.2 Evaporative Drying

The printing ink consists of several components such as resins, pigments, and solvents, the drying of which is achieved partly by *evaporation*. The following processes take place:

- conversion from liquid (solvent) into vapor state and
- eduction of steam generated or steam-loaded air.

As a rule, only as much heat should be supplied as is dissipated in the generating steam, regardless of the type of heat supply and bearing in mind the economic efficiency and the careful treatment of the product to be dried. This rule is to be followed particularly when designing a dryer for printing presses since the substrate should be heated as little as possible for known difficulties such as register inaccuracy, variations of the visco-elastic properties of the substrate, and warping. The solvent evaporates when a printing ink is dried by evaporation. The drying process is determined by the *heat and material transport* in the boundary film on the surface of a liquid (printing ink).

The surface temperature, and above all the air speed along the substrate surface as well as the partial pressure difference are the main parameters for the *drying speed* [1.7-2, 1.7-3]. Drying by evaporation is accelerated by additionally enforced convection. Therefore, heating via heat radiators and/or hot air is to be com-

Table 1.7-1 Pros and cons of IR drying

Pros	Cons
Faster penetration of the printing ink resulting in more favorable pile behavior with respect to ink set-off	Higher investment leading to a higher hourly rate of the press due to the installation of the IR system
Considerably faster final drying	Higher energy consumption
Lower powder consumption for spraying the printed sheets before they are delivered in the pile, resulting in better print quality and less dirt accumulation in the press	Increased temperature in the machine as well as in the press room
Print finishing is made easier by less powder application	

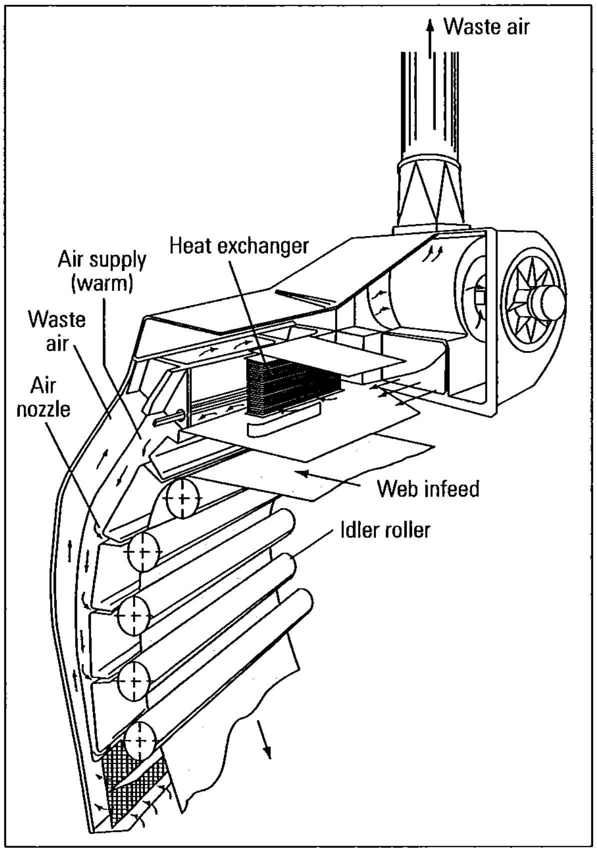


Fig. 1.7-7
Vertical blast dryer (with single-sided drying) in a web-fed gravure press

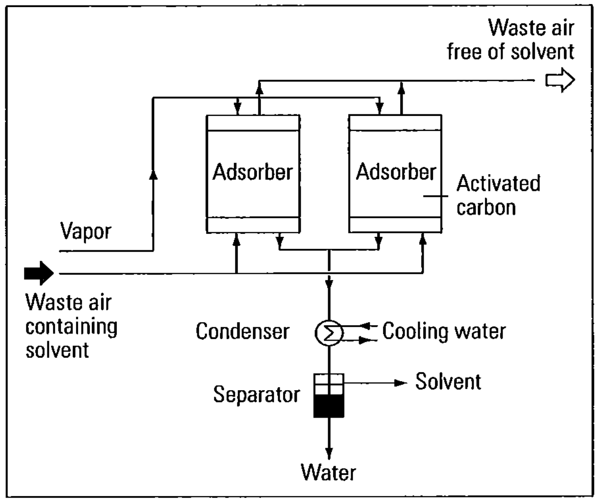


Fig. 1-7-8
Flow chart of the Supersorbon method (simplified representation) (Lurgi [1.7-4])

bined with optimum air conduction. Figure 1.7-7 shows a *vertical blast dryer* used for gravure printing.

This dryer is optimized with regard to aerodynamics. Such vertical blast dryers are used for drying printing inks containing low-boiling solvents mainly used in gravure and flexographic printing. The organic vapors generated are taken up via adsorption on activated carbon in solvent recuperative systems.

The supersorbon method (fig.1.7-8) for *solvent recuperation* [1.7-4] includes the following processes:

- *Charging (adsorbing).* Air containing solvent is extracted by a fan at the evaporation points (e. g., gravure printing press, vertical blast dryer) and conveyed from the bottom upwards by one or several adsorbers filled with activated carbon. The solvent is adsorbed by the activated carbon. Solvent-free air penetrates at the top (fig. 1.7-8). Charging of the adsorbers is continued until it "breaks through," that is, until the vapors are no longer sufficiently adsorbed.
- *Regenerating (desorbing).* Extracted activated carbon is regenerated in reverse exhaustion flow direction by way of desorption with water vapor. The activated carbon is heated to a little over 100 °C; the solvents – including higher-boiling point solvents – are vapor-expelled. They condense in the water of the container and can now be separated from the water and become reusable.

Heatset Dryer

Unlike gravure printing, printing inks used in *web offset* contain a high portion of high-boiling point mineral oils (heatset oils). Low-boiling point oils cannot be used as such printing inks become dry on the rollers while the ink is transferred in the roller-type inking unit. Heatset inks used in web offset contain between 20% and 40% high-boiling point mineral oils. Therefore, appropriately adapted evaporative dryers are to be used in web offset.

"Suspension dryers" (fig. 1.7-9) are mainly used as drying units in web offset (see also sec. 2.1.3). The web is routed contact-free through those dryers without guid-

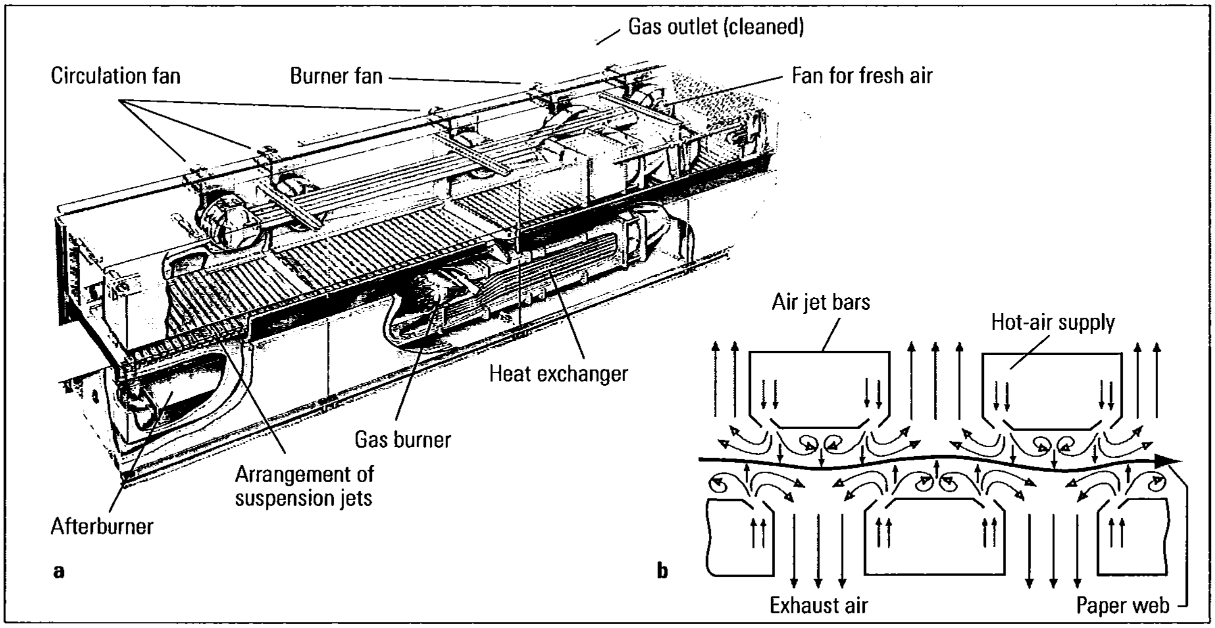


Fig. 1.7-9 Suspension dryer for web offset presses.
a Sectional drawing;
b Web guidance with suspension jets (Ecotherm, Heidelberg)

ing elements. This is achieved by a well-directed blower stream in the hot-air dryer. Floating dryers are roughly classified according to the type of air stream applied to the surface of the web of fabric. They all have in common that the web is conveyed at high speeds through the dryer without it contacting any surface. A web that is transported in such a way demands high standards regarding method, mechanics, and control engineering in order to achieve optimum and economic drying and a smooth production flow. The waste air is directed via an after-burner. The heat generated during combustion is used again to heat the dryer.

1.7.1.3 Problems in Practical Operation

In general, physical drying is influenced by various parameters. The following examples will illustrate this:

- Drying becomes more critical if the *penetration speed* decreases, or if the ink application increases in the image, or if the grammage of the substrate increases.
- *Blistering* may occur with high grammage, double-coated, and heavily calendered papers. Water vapor penetration capacity is reduced to a minimum due to the surface densification. High ink application might cause the temperatures to rise so high – particularly with short dryers – that the water vapor generating in the paper partly splits the paper, which in turn results in blisters and a large number of waste sheets. The temperature of the dryer and the print speed are then reduced.
- Drying is dependent on the speed at which the paper web passes through the dryer. The temperature of the dryer should be set according to the paper grammage: the higher the *grammage*, the higher the temperature. In order to achieve sufficient drying, the paper web needs to remain in the drying area for 0.8 to 1 second. If the paper web is conducted at a speed of 8 m/s, the dryer needs to be at least 8 m long. Drying systems therefore require considerable space. Due to dehydration, the paper web can become fragile and wavy and starts shrinking. Print finishing thus becomes more and more difficult. For this reason, *remoistening* with water is recommended for web offset printing presses. The water can either be sprayed onto the web or applied by rollers.

1.7.2 Chemical Drying/Curing

1.7.2.1 Oxidation

In offset printing on absorbing substrates, inks first dry by penetration (see sec. 1.7.1) and then by oxidation and polymerization. Final drying of the printing ink film is effected only by oxidation and polymerization of the drying oils and resins. The printing ink film receives appropriate cross-linking and consistency against rubbing-off and abrasion, it has, however, to preserve adequate elasticity for the product to be used.

Oxidative drying of offset inks containing drying oils is effected without additional units by molecular linkage with oxygen from the air. For that, the ink layer on the sheet to be linked should be supplied with sufficient oxygen in the delivery pile. The necessary space between the sheets can be increased by *powdering*, and oxygen can then diffuse in the piles. Powdering serves to support drying in the pile, and also to avoid smearing the image on the underside of the top sheet.

Even though accelerated by *catalysts* in the printing ink, drying by oxidation takes quite a while. Metallic soaps, that is, cobalt or manganese combined with oil-soluble acids, are used as catalysts.

Cobalt driers in the ink are "surface driers", that is, the drying process is started on the ink surface and slowly proceeds to the substrate. *Manganese* functions as a through-drier. Frequently, *compounds* are used as driers guaranteeing a straightforward drying process. There is an optimum quantity of *drier additive* for every ink/substrate combination. Adding too much additive can cause the ink to dry on the rollers of the inking unit. Transfer of ink onto the substrate is then likely to be disturbed.

Parameters influencing printing ink drying are:

- in the printing ink: pigment, vehicle, drying agent;
- in the substrate: pH value, coating composition, penetration behavior, water absorption, temperature in the delivery pile;

and in offset printing:

- dampening solution with: pH value, water salt content, water hardness, alcohol percentage.

Figure 1.7-5 shows the relevant spectrum of electromagnetic waves specific to ink drying. The IR radiation is of no direct significance for chemical (oxidative) drying. It is merely the elevation of temperature that brings about increase in reaction speed. However, UV radiation and ionizing radiation (electron-beam) in comparison produce radiation-linking chemical ink drying.

1.7.2.2 UV Drying/Curing

UV drying of printing inks (and varnishes) is based on radical polymerizable vehicles. UV inks with appropriate UV dryers are suitable for sheet-fed printing presses and web presses. Drying between the print units – inter-unit drying – (fig. 1.7-10) can be used to prevent a reversal of the ink splitting in the following inking unit. In flexographic and gravure printing, drying has to be carried out after each inking unit (e.g., straight (recto) printing and perfecting) because of the ink properties (ink trapping, etc.). Very often an overall drying becomes necessary after the last inking unit, possibly at a higher output rate.

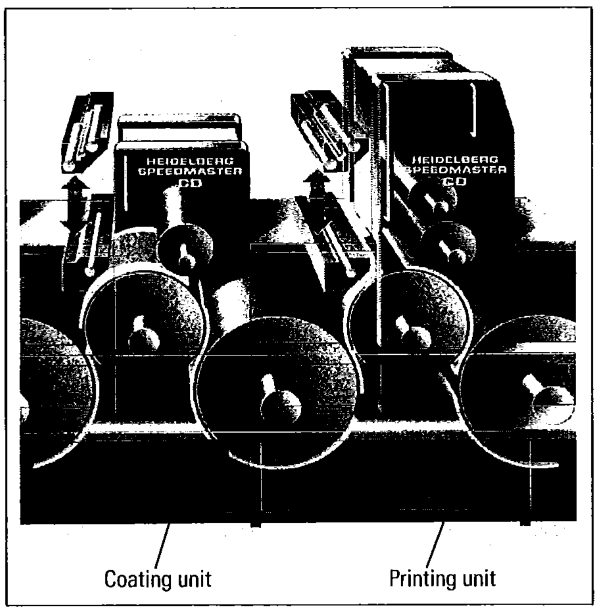


Fig. 1.7-10
UV inter-unit dryers for sheet offset printing press after printing unit and coating unit; UV dryer (blue) can be replaced by IR dryer (red), (IST Strahlungstechnik metz)

In case of UV drying, the ink film polymerizes and dries completely as soon as radiation occurs. Polymerization takes fractions of a second. The UV drying method, however, requires *special inks* containing completely different binders (vehicles) and additional photoinitiators (see sec. 1.5.2). The color black prevents UV radiation from penetrating in the ink layer and the curing effect is less than with chromatic colors or varnishes.

Conventional UV dryers work with one or several *mercury vapor lamps* (fig. 1.7-11, see also fig. 2.1-61). The wave length range lies between 100 and 380 nm. The system is enclosed by a reflector housing. Optimum cooling and extraction of generated ozone is necessary for the complete system. The units are designed in such a way that the permissible threshold limit value of 0.1 ppm (parts per million = one millionth of the volume of the substance in question, e.g., air) is not exceeded and damage (e.g., irritation to the mucous membrane) to one's health is prevented.

Excimer

The excimer radiator is a special type of UV lamp (fig. 1.7-12) with monochromatic light (mostly used with a wave length of 308 nm). Advantages of this radiator include:

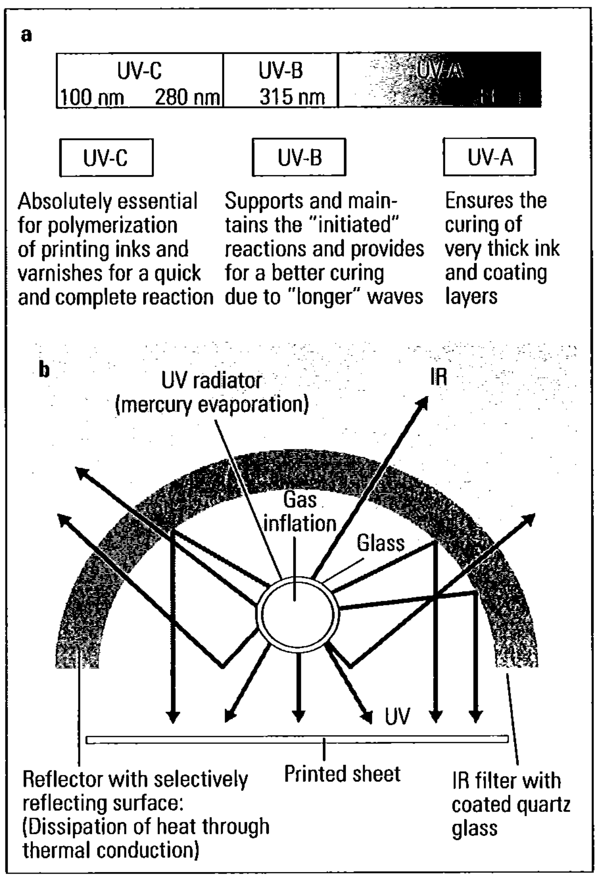


Fig. 1.7-11 UV drying system.
a Ranges of the UV spectrum and their effect;
b UV radiator reflector system (Dr. Hönle)

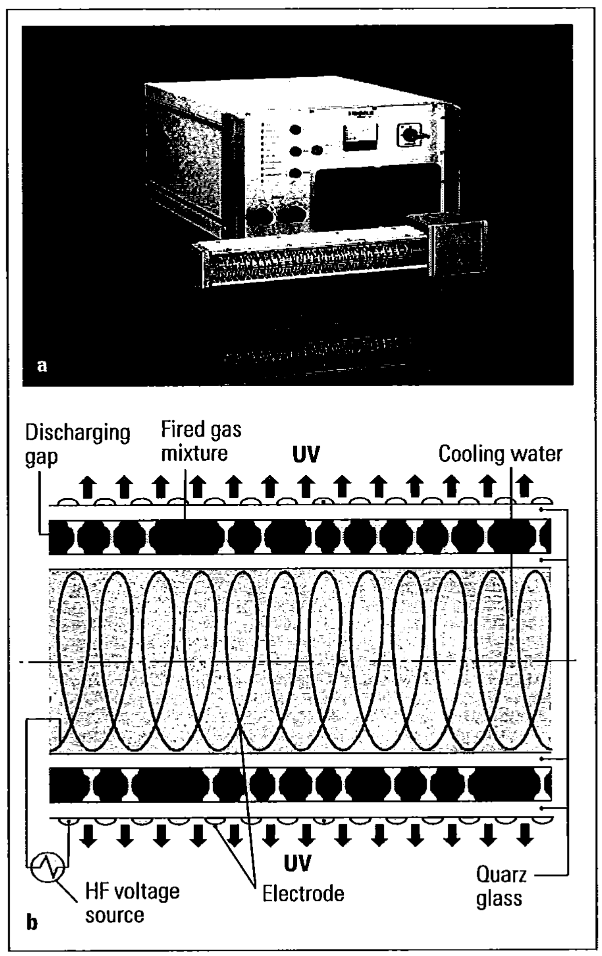


Fig. 1.7-12 Excimer radiator.
a Excimer system with radiation unit and ballast;
b Structure of an excimer radiator (Heraeus Noblelight)

- no heating of the paper as radiation does not involve any IR,
- no ozone generation at 308 nm,
- better utilization of electrical susceptibility for the drying process.

The disadvantages are:

- The power (up to 50 watts/cm radiator length) of today's excimer radiators is still considerably lower than the power density of mercury vapor lamps (up to 250 W/cm). If radiation takes place in an inert gas atmosphere (e.g., nitrogen), it will still result in the desired drying performance.
- The ink photoinitiator system needs to be adapted to the particular wave length. Conventional UV lamps are polychromatic and therefore cover a greater bandwidth of photoinitiators.

Excimer dryers are particularly interesting for flexographic printing in association with the printing of heat-sensitive substrates (e.g., foils). The pros and cons of UV drying are summarized in table 1.7.2.

1.7.2.3 Electron Beam Drying/Curing (EBC)

Electron beam is an *ionizing radiation* of such high energy that molecules in the vehicle of a printing ink are ionized, thus causing the release of free radicals. Today, electron beam drying is used with particular print products (e.g., food packages, due to the absolute drying of ink and the destruction of any micro-organisms in the substrate). Appropriate drying systems and inks are comparatively expensive.

In principle, the same vehicles and inks can be used for EBC and UV drying. Owing to high energy, a sufficient number of initial radicals are released in the vehicle itself; therefore there is no need to add expensive photoinitiators (resulting in better storage stability of the inks). It is, however, absolutely essential to use radiation in an inert gas since the presence of oxygen not only considerably impedes curing, but also leads to a radiation-induced, oxidative degradation of the ink layer and, possibly, of the substrate. If oxygen is excluded, the dose of radiation required for drying the ink layer only causes minimal damage.

With electron-beam drying no unwanted high heating of the substrate or the printing ink layer occurs. Figure 1.7-13 shows the possible arrangement of radiators.

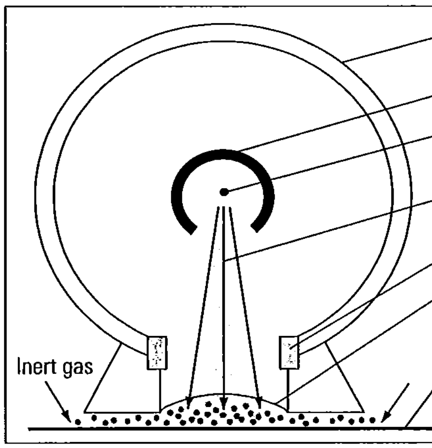


Fig. 1.7-13 Principle of electron-beam tube (MEC)

Table 1.7-2 Pros and cons of UV drying

Pros	Cons
UV inks are completely dry upon radiation	Higher capital investment due to accessory equipment
No damage to the prints by ink set-off or sticking	Higher costs for printing inks, washing agents, etc.
Immediate print finishing is possible (e.g., trimming, scoring, stamping, punching, etc.)	Relatively short service life of UV lamps
Printing on non-absorbent substrates (metal, foils) is not difficult	Less suitable for absorbing substrates
	Fogging/misting (due to the rheological properties of ink, e.g., tack) with UV offset inks results in a limiting of the printing speed

Table 1.7-3 Pros and cons of EBC drying

Pros	Cons
Immediate drying Radiated product stays cold	High investment costs X-radiation shield is a "must"
Simultaneous drying of both sides in recto/verso (perfecting) printing and radiation only from one side of the substrate (not possible for tin or metallic foils)	Radiation inside a protective atmosphere (e.g., nitrogen)
	Substrate is likely to get damaged if the radiation dose is too high
	Higher cost for printing inks

An electrically heated tungsten ribbon serving as an electron-beam source is admitted to the web.

The pros and cons of EBC (electron beam curing) drying are summarized in table 1.7.3.

1.7.3 Auxiliary Drying Techniques

As described in section 1.7.1, the drying process in conventional letterpress or sheet-fed offset takes place in two steps: penetration, followed by oxidative polymerization of the printing ink.

The penetration process is effected immediately on ink transfer in the printing zone. Penetration provides higher viscosity for the ink film lying on the substrate. Quite often, however, this hardening effect is not enough to avoid set-off effects and, in extreme cases, complete blocking (sticking) of the paper in the delivery.

1.7.3.1 Powder Spraying

The printed sheets in the delivery are *powdered* to avoid set-off or blocking effects (fig.1.7-14). The fine powder layer is distributed by compressed air, thereby preventing the ink of the freshly printed sheet from getting too close to the reverse side of the top sheet (fig. 1.7-15, see also fig. 2.1-56 for powdering on both sides with perfecting jobs). The colorless (white) powder grains serve as "spacers" ensuring oxidative drying by inclusion of air. These grains lying on the printed sheet provide an air cushion between the individual printed sheets. Grain sizes vary from 15 to 75 μm (material: colorless mineral or vegetable based substances). As a general rule one can say that

- the rougher the substrate, the more coarse the grain should be,
- the thicker the ink layer, the more powder is needed.

Incorrect powdering can seriously affect the usually good print quality, in particular with regard to gloss.

Mineral and vegetable based powder types are classified as:

- *Calcareous* (mineral-based) spraying agents available in different graining. They are essential for cardboard printing.
- *Starch-containing* (vegetable-based) products based on corn. They are available in fine graining only and therefore suitable for processing papers of up to around 100 g/m² only. Since they are not as hard as calcareous agents, ink abrasion is considerably less.

The printing plates, too, are less affected by abrasion through soft (vegetable) powders. In multicolor printing, calcareous (mineral) powders deposit on the rubber blanket in the form of dust acting like sandpaper against the printing plate, thereby considerably reducing its service life.

1.7.3.2 Silicone Application

Coating the web in a commercial web offset press with a thin film of silicone oil-in-water emulsion prevents the products getting smeared in the folder. After printing, the ink beneath the silicon layer is not fully dry even after a few days and may still be smudged after the silicon layer has been rubbed off.

1.7.4 Measuring Techniques

The finishing of freshly printed sheets in particular requires sufficient abrasion resistance and pile resistance (no offsetting and blocking of sheets). For basic balancing between ink and substrate regarding ink